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LOW TEMPERATURE MATERIALS GROWTH AND PROCESSING DEVELOPMENT FOR FLAT PANEL DISPLAY TECHNOLOGY APPLICATIONS

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I. SUMMARY

The primary purpose of this research effort is in developing process technologies that focus on lowering of the fabrication temperatures for flat panel displays. We also intend to work on the improvement and understanding of the important physical and electrical properties of thin film phosphors and other active electronic devices under consideration for use in displays, such as field emitters and thin film transistors.

Our present approach is to:

- Establish a facility for the deposition and processing of thin film phosphors and α-Si, including simple device fabrication,
- Development of the necessary physical measurement techniques to evaluate the films/processes being explored in the above,
- Cultivate industrial partners to aid in the transfer of knowledge gained during the research and exploration phase.

An important aspect of this work will be the incorporation of transient thermal processing techniques, mainly pulsed *uv*-laser processing, into the development stream. We will address several aspects of non-equilibrium thermal processing in this research. This includes deposition, doping, and crystallization of thin film silicon for display driver devices.

The present team working on this effort at OGI is:

• Thin film transistor and transient thermal processing-

Prof. T.W. Sigmon	Principal Investigator	sigmon@eeap.ogi.edu
Dr. Chris Barbero	Post Doctoral Research Associate	
Mr. Gary Guist	Ph.D. Research Assistant	

• Field Emission Flat Panel Display Technology — bella@eeap.ogi.edu

Prof. Tony Bell	Principal Investigator	
Mr. Kit-Sing Mak	Ph.D. Research Assistant	

• Electroluminescent Display Technology — solanki@eeap.ogi.edu

Prof. Raj Solanki	Principal Investigator	
Mr. Weiran Kong	Ph.D. Research Assistant	

In addition Dr. Barbero is in charge of the display laboratory development and works closely with the Ph.D. students.

II. TECHNICAL REPORT

1) THIN FILM TRANSISTOR DEVELOPMENT T. SIGMON

This effort is pursuing the fabrication of poly-Si and poly Si/Ge thin film transistors. As the principal investigator is the primary developer of pulsed *uv*-laser processing of Si, the intent will be to explore the use of this technique in the fabrication of thin films of Si on various substrate materials. We presently have a gas immersion laser doping (GILD) system established at OGI. Our initial effort will be to adapt our one dimensional GILD process model for Si on SiO_2. This will enable us to plan our experimental processes for developing a high quality, polysilicon layer on substrates suitable for flat panel display technology. During the last quarter we established a plan to develop an *in situ* process for monitoring GILD processing of thin Si films on dielectric's. The techniqne uses a laser probe to monitor the processing of the amorphous and/or polysilicon films to be utilized in the TFT development.

The GILD process uses an excimer laser pulse to melt the surface of a material. A normally incident, continuous-wave (CW) 'probe' laser is reflected off the sample at the location of the excimer pulse to monitor the sample's change in reflectivity with temperature. Molten silicon reflects about 70% of the incident light for all wave lengths of interest. This reflectivity change with time identifies how long the material is molten. A typical 'melt pulse' is shown in Fig. 1, which shows the reflectivity of the material before-i), during-ii), and after-iii) melting. For silicon at 633nm, a 32% change in reflectance is typical. Knowledge of the melt pulse is an important *in situ* process monitor, from which the melt depth can be extracted.

Identifying a melt pulse is straightforward for single material systems. Multilayer structures, such as an amorphous silicon/oxide/glass structure used in thin film transistors, have the added complexity of optical interference between layers. Here, the probe laser reflected intensity from the multilayer stack depends on each layer's optical thickness, so this intensity can vary quite a bit. Yet, the reflected intensity from molten silicon remains at 70%. Figure 2 illustrates such an unoptimized structure. Since the melt pulse can only be seen if the reflected intensity from the molten surface is appreciably different from that when it is cool, the multilayer stack must be designed to provide a minimum reflectance when it is cool.

As we are confined to work with certain materials (*i.e.*, the optical constants are fixed), the only way to change thé optical thickness is to change the physical thickness. Computer programs have been developed to calculate reflectance versus wavelength and thickness, and used to optimize the thicknesses of the layers in the stack for minimum reflectance

without excimer laser heating. Figure 3 shows the reflectance of unpolarized light incident 8° from the normal from a silicon on an oxidized silicon substrate, for two oxide thicknesses. The thickness of the top silicon layer is varied along the x-axis. The 8447Å oxide curve shows a minimum reflectance for a silicon thickness of about 0.115λ, which is 728Å for 633nm and 595Å for 514nm light. Note that the effect of optical interference introduces a new degree of freedom not present in single material systems. That is, control of such interference allows the design of stacks having much lower 'cool' reflections, thereby providing melt pulses with greater changes in reflectance than the 34% change typical from silicon substrates. An example is shown in Fig. 4, where 59nm of silicon on 300nm of SiO_2 on a silicon substrate produces a 65% change in reflectance upon being melted.

The probe laser wavelength was also optimized. Figure 5 shows a plot of reflectance versus wavelength for silicon, amorphous silicon (both LPCVD and *e*-beam evaporated), and liquid silicon, assuming infinite film thicknesses. Longer probe laser wavelengths offer greater changes in reflectance between molten and solid materials. But lower wavelengths have shorter absorption depths, and therefore better probe the 'surface.' An intermediate wavelength of 514 nm for an Ar laser was chosen as a compromise.

2) FIELD EMISSION FLAT-PANEL DISPLAY TECHNOLOGY A. BELL

Computation Program

- Background:

It is important to understand catastrophic melting of the field emitter as a potential life-limiting mechanism for FED displays. Due to normal process variations, the emitter radii in a FED array will vary somewhat and because the corresponding variation of emission current from each emitter will be very much greater. The danger is that the smallest radii emitters in the array may draw excessive current and then self-destruct in a melting/vaporization induced vacuum arc. With this in mind, the following goal is being pursued:

- Goal:

To be able to calculate temperature versus time for field emitters of different materials such as silicon, molybdenum, refractory carbides and also of diamond.

- Progress:

The approach taken is to develop simplified analytical models and use these as bench-marks to check the results obtained from commercial software packages such as the ANSYS software from Swanson Associates which can tackle non-linear problems that can accurately mimic the behavior of real systems.

Based on the work of [1] we have developed temperature/time models for field emitter apex temperatures for the case with no radiation and with temperature independent resistivity and temperature independent thermal conductivities.

This model has been used to check the results of the ANSYS finite-element program which is capable of handling mixed problems-in this case thermal and electrical. The accuracy of this model is better than 0.5%. Work is now underway to include the temperature dependence of both thermal and electrical conductivity.

- Experimental Program:

In order to study the stability and life-limiting mechanisms of the kind of small current/time variations of field emitters and to examine ways of cleaning the emitters by plasma heating or by using the Joule heating of the emitters in order to smooth out and to clean the surface of the emitters. In order to perform cleaning by the Joule heating, care must be taken to avoid run-away heating which would destroy the emitter. The above calculations on the temperature/time relationships will be valuable when available.

- Future Work:

The above work will be continued with a view to completing the calculations in the next quarter, if possible.

3) ELECTROLUMINESCENT DISPLAY TECHNOLOGY R. SOLANKI

During the last quarter, our efforts were directed at (a) characterizing the blue electroluminescent (EL) phosphors and (b) installation of the atomic layer epitaxy (ALE) reactor.

Blue EL Phosphor

We have continued to work with Planar Systems to better characterize the blue $SrCaGa_2S4$:Ce EL phosphor in order to optimize its optical emission properties. Several sets of sputtered thiogallate films were processed under different conditions; various time/temperature-anneal cycles, as well as nucleation layers. First, the crystalline properties of these films were examined using our grazing incidence X-ray system. The top electrodes were then sputtered on these samples to evaluate their electrical and optical behavior.

The electrical characterization included our routine measurement of the quenching field, I-V, C-V, Q-T, and field-t behavior. However, these measurements are not sufficient to link the process conditions to the optical emission efficiency. Therefore, we have added one more parameter, the transferred charge to our list of our electrical tests. It is generally accepted that the excitation of the activator occurs by impact excitation by the hot electrons, hence the conduction current and the transferred charge (from one interface to another) in

the active layer are important parameters in determining the EL device characteristics. In particular, we found that the transferred charge and its relationship to the emission properties of the EL devices provide a direct method for evaluating the process parameters.

The transferred charge was measured by employing a Sawyer-Tower circuit that includes a large 'sense' capacitor. Data was collected in real time using a digitizing oscilloscope and a PC. An example of these measurements is shown in Fig. 6 for a set of thiogallate phosphors annealed at different temperatures. The aluminum electrodes for these samples were 3mm in diameter and the measurements were done at 1kHz. It can be seen that sample K683, which was annealed at 800C has a significantly higher brightness for a given amount of transferred charge (delta Q) then sample K679 that was annealed at 450C. The rest of the samples were annealed in the intermediate temperature range. This implies that the samples that were annealed at higher temperatures were more efficient light emitters. This could be due to higher activation efficiency of the Ce ions or better crystalline structure, hence fewer trap sites. We have not yet resolved this issue. Also, the amount of transferred charge was found to be independent of the driving frequency up to our limit of 10kHz.

ALE Reactor

The Ale reactor is being installed. Our main effort has been to redo some of the plumbing to convert the gas receptacles from metric to US standards. We expect to start our calibration runs in the very near future and plan to have some results by the next quarterly report.

III. REFERENCES

1. B.Dolan and W.P. Dyke, *Phys. Rev.* **91** 1054-1057 (1953).

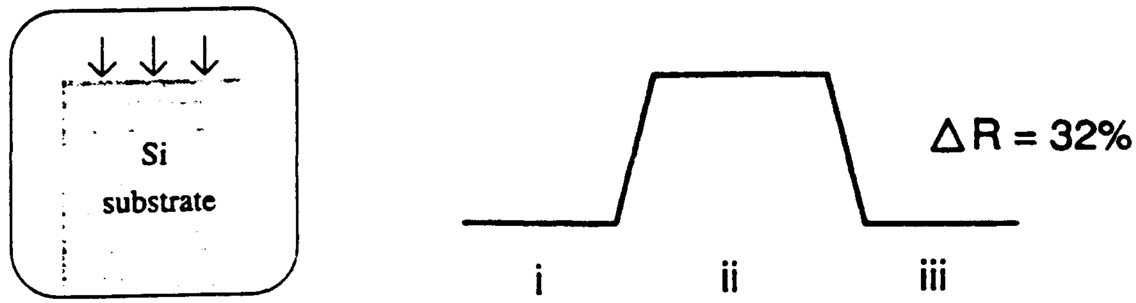

Fig. 1 Typical melt pulse for Si substrate, before (i), during (ii), and after (iii) melting

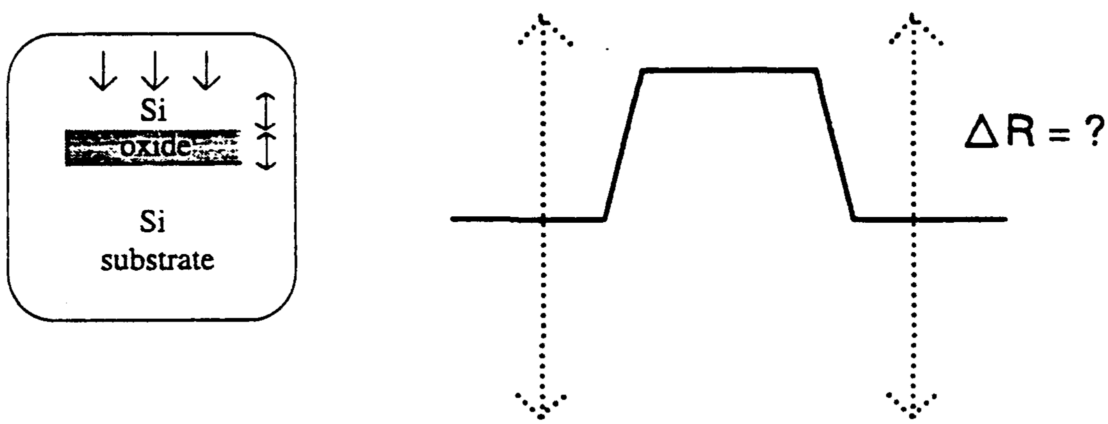

Fig. 2 Multilayer sample (unoptimized)

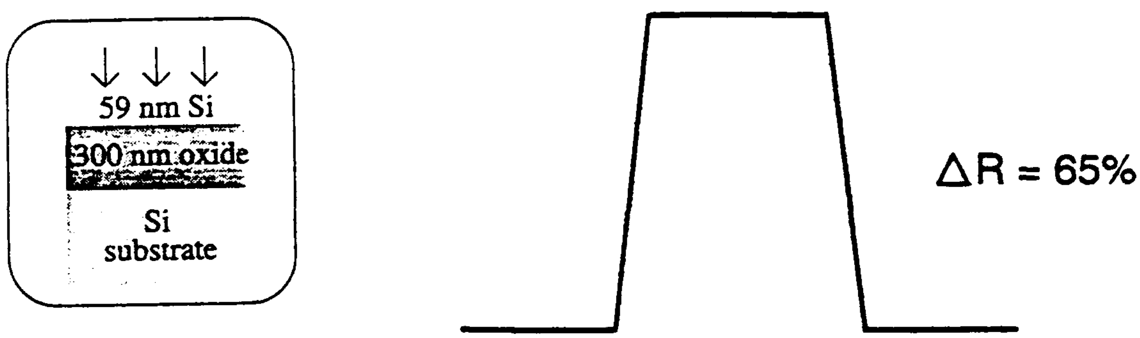

Fig. 4 Optimized multilayer sample

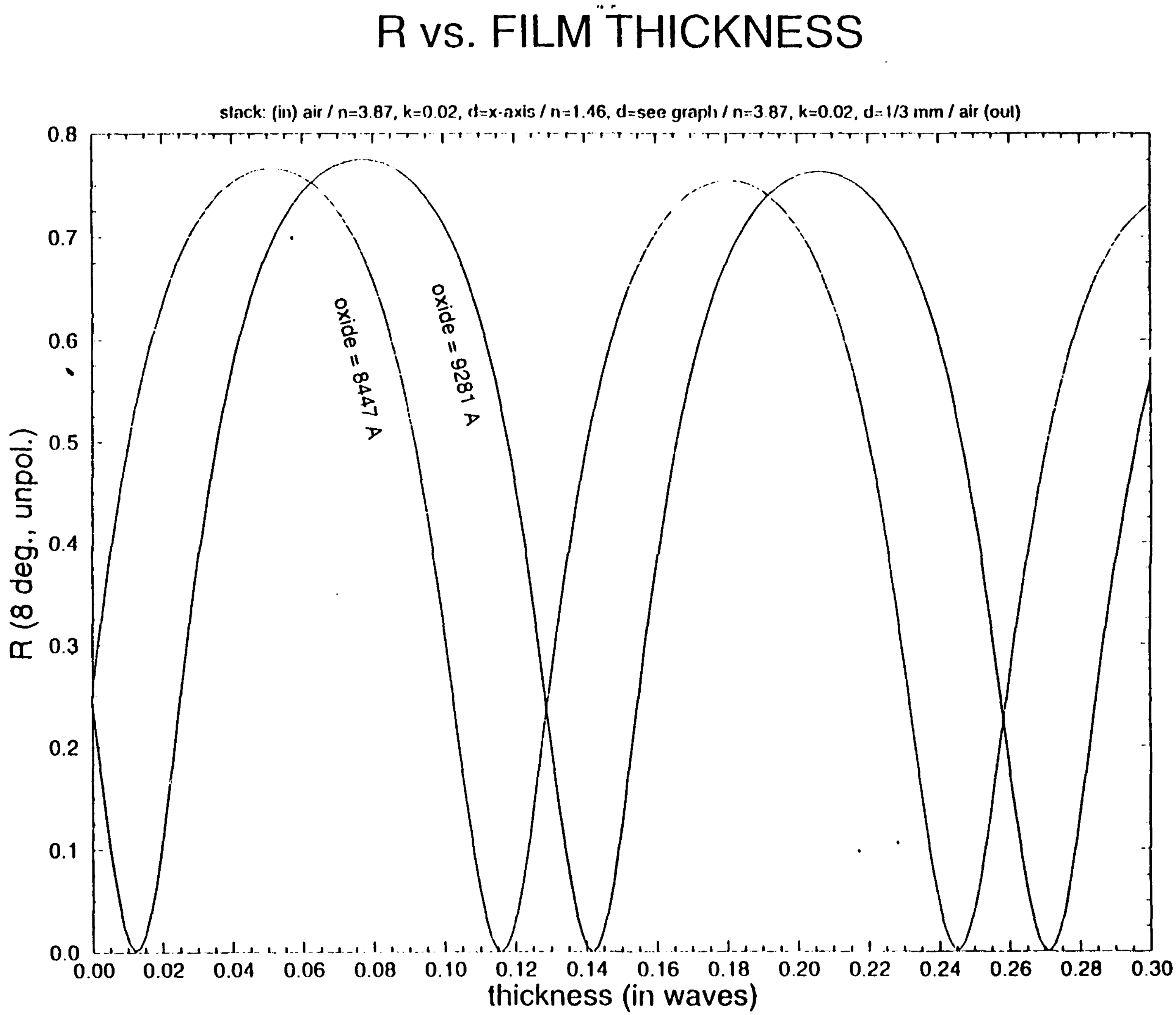

Fig. 3 Reflectance versus top silicon layer thickness, shown for two thicknesses of oxide. Notice how much the reflectivity changes for different silicon thicknesses.

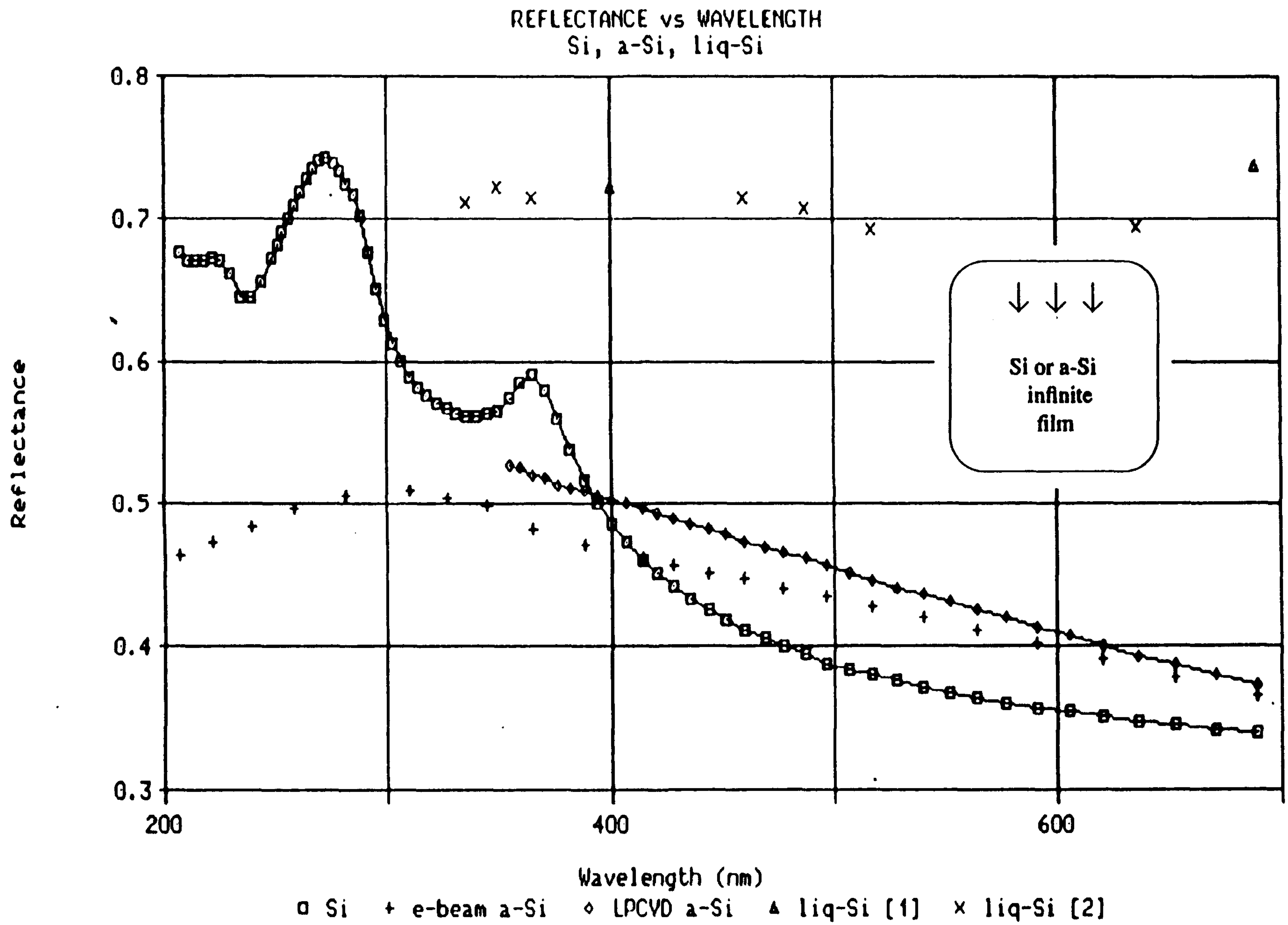

Fig. 5 Reflectance of Si, a-Si, and liquid Si versus wavelength.

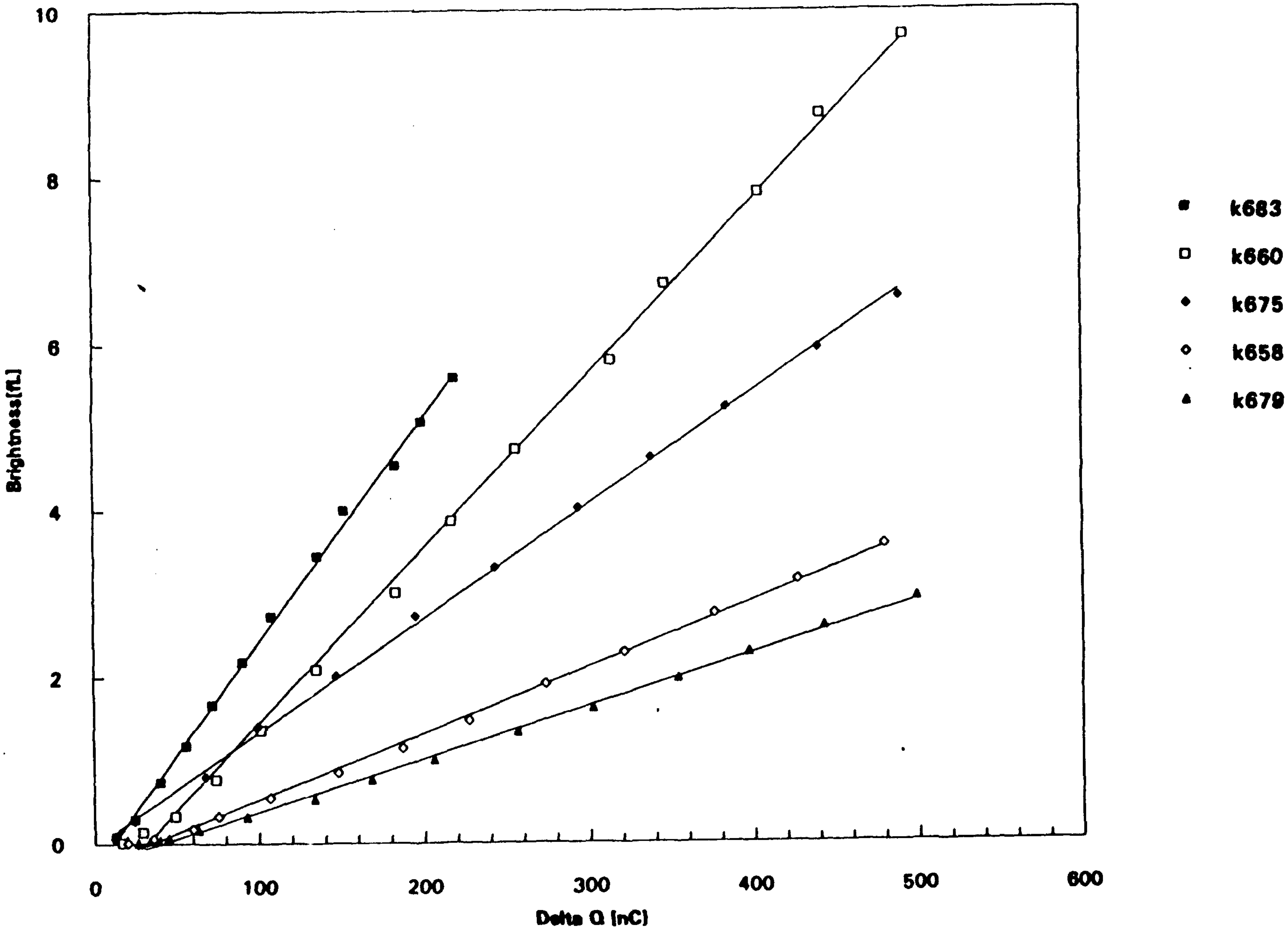

Figure 6. Plot of transferred charge(Delta Q) versus the brightness for a set of thiogallate phosphor samples annealed at different temperatures.